Impact Evaluation of 2010 Rhode Island Custom Process and Compressed Air Installations

National Grid

Prepared by KEMA, Inc.

August, 2012

Table of Contents

List of Exhibits

1. Introduction

This document summarizes the work performed by DNV KEMA during 2011 and 2012 to quantify the actual energy and demand savings due to the installation of three Custom Process and Compressed Air measures installed through National Grid's Energy Initiative and Design*2000* energy efficiency programs in 2010 in Rhode Island (RI). This report also summarizes the sampling and analysis procedures used for developing the population level results, which are based on the combined results of the Rhode Island sites and a concurrent study of National Grid Custom Process and Compressed Air projects in Massachusetts.

1.1 Purpose of Study

The objective of this impact evaluation is to provide verification or re-estimation of electric energy and demand savings estimates for a sample of Rhode Island Custom Process and Compressed Air projects through site-specific inspection, monitoring, and analysis, and to develop new realization rates for the combined Custom Process and Compressed Air populations in Rhode Island. The results of the project studies are combined with the results from a concurrent study of National Grid Custom Process and Compressed Air installations in Massachusetts to determine appropriate population level realization rates for the combined Custom Process and Compressed Air populations in Rhode Island.

This impact study consists of the following four tasks:

1. Develop Sample Design
2. Develop Site Measurement and Evaluation Plans
3. Data Gathering and Site Analysis
4. Report Writing and Follow-up

1.2 Scope

The scope of work of this impact evaluation covered the 2010 Custom Process and Compressed Air end-uses, which include new equipment and/or control systems and strategies. This impact evaluation includes only measures which primarily reduce electricity consumption.

2. Description of Sampling Strategy

The primary focus of the sample design task was to examine various precision scenarios for the Custom Process and Compressed Air programs in Rhode Island. The entire sample design process, including the scenarios considered, is described in the work plan for this project. Due to the fact that Custom Process and Compressed Air measure categories each account for a small proportion of RI's overall energy efficiency portfolio, the decision was made to combine them into one class to reduce the sample size requirements for this study. In addition to estimating realization rates for RI, the results obtained from the RI sample will be combined with the MA results to determine a combined realization rate. Results from National Grid's Massachusetts Custom Process and Compressed Air evaluations were developed previously and are described in the final report for the MA-LCIEC Project 13[1].

The project populations for National Grid, based on projects completed in 2010 are summarized in Table 1.

Table 1: RI& MA Population Statistics – Custom Process and Compressed Air

State	Projects	Total Savings	Average Savings	Minimum	Maximum	StdDev	CV
Massachusetts	67	15,405,124	229,927	13,006	1,580,593	321,666	1.40
Rhode Island	10	2,741,081	274,108	33,116	829,674	281,347	1.03
Total	77	18,146,205					

The initial design approach was to support the estimation of annual kWh savings realization rates for National Grid's programs in Rhode Island. While annual kWh savings was the primary variable of interest, National Grid is also interested in achieving accurate results for coincident summer peak demand (kW), in order to meet the ISO-NE guidelines for ±10% precision with 80% confidence for their overall portfolio of programs.

The sample design and anticipated precision for annual kWh and summer kW is presented in the following section. The evaluation sample for this study was designed in consideration of the requirements for a 90% confidence level for energy (annual kWh) and an 80% confidence level for coincident peak summer demand (kW).

2.1 Annual kWh Sample Designs

KEMA presented several preliminary sample designs stratified by annual kWh for National Grid's Custom Process and Compressed air programs in Rhode Island. The parameters considered in the sample design are the number of sample observations planned and the anticipated error ratio of the quantity being estimated which, in this case, is the realization rate for evaluated savings. The error ratio is a measure of the strength of the relationship between the known characteristic (i.e., tracking system savings) and the unknown population characteristic (i.e., evaluated savings). For this study an error ratio of 0.5 was assumed for energy savings, based on the results of prior studies in MA. The error ratios for summer and winter kW savings were assumed to be 0.8 and 0.85, respectively. These are consistent with what was used for planning the 2010 MA statewide study. The final annual kWh design, which served as the basis for the RI sample size of 3 sites, is shown in Table 2.

12011 Electric Energy Efficiency Annual Report, Massachusetts Electric Company Nantucket Electric Company d/b/a National Grid, August 2012, Appendix C, Study 22", "Impact Evaluation of 2010 Custom Process and Compressed Air Installations", prepared for the Massachusetts Energy Efficiency Program Administrators and the Massachusetts Energy Efficiency Advisory Council, by KEMA, May 2012.

Table 2:RI Custom Process and Compressed Air Sample Design

State	Stratum	Maximum KWh Savings	Total Projects	Total Annual MWh	Projects in Sample	Case Weight
Rhode Island	1	269,462	8	1,100,044	2	4.00
	2	829,674	2	1,641,037	1	2.00

While the individual results for Custom Process and Compressed Air in Rhode Island were not expected to produce estimates with great precision, consideration was made for the possibility that they may be combined with Massachusetts results for determining an overall realization rate for these measures for use in Rhode Island. Combining Rhode Island results with Massachusetts results from similar and concurrent studies was considered due to the high cost of conducting Rhode Island specific evaluations with large enough samples to produce statistically representative results and the fact that the National Grid's program design and delivery infrastructure is similar in both state's subsidiaries. Anticipated precisions for the RI, MA and combined results are shown in Table 3. The actual precisions achieved in these studies are provided in the results section of this report.

Table 3: Custom Process and Compressed Air Anticipated Precisions for Annual KWh

Measure	State	Projects	Total KWh Savings	Error Ratio	Confidence Level	Planned Sample Size	Anticipated Relative Precision	Error Bound
Custom Process and CAIR	MA	67	15,405,124	0.5	90%	18	±13.62%	2,098,540
Custom Process and CAIR	RI	10	2,741,081	0.5	90%	3	±40.21%	1,102,111
Custom Process and CAIR	Total	77	18,146,205	0.5	90%	21	±13.06%	2,370,341

2.2 Coincident Summer Peak Demand (kW) Sample Designs

Before deciding on a final sample design, it is useful to examine the estimated summer kW precision that could be achieved with a sample of this size. The error ratio for summer kW savings from previous custom electric measure studies were higher than that for annual kWh, so a value of 0.8 was assumed for this calculation. Table 4 reports the anticipated precision for summer kW savings, based on a confidence level of 80%. Neither of the anticipated precision levels meets the target of ±10%, but as these measures are a small portion of the National Grid portfolio, they were acceptable.

Table 4: **Anticipated Precision for Summer KW**

Measure	State	Projects	Total Summer KW Savings	Error Ratio	Confidence Level	Planned Sample Size	Anticipated Relative Precision	Error Bound
Custom Process and CAIR	MA	67	1,792	0.8	80%	18	±16.99%	304
Custom Process and CAIR	RI	10	326	0.8	80%	3	±50.14%	164
Custom Process and CAIR	Total	77	2,118	0.8	80%	21	±16.31%	346

2.3 Final Samples

Based on these stratified designs, random samples of projects were selected from the tracking system data. Table 5 presents the list of three projects selected as the final sample for RI Custom Process and Compressed Air projects. During the evaluation, it was determined that the Compressed Air project had not functioned properly in its initial location and subsequently the primary component of the project was being relocated to another part of the facility. After numerous unreturned calls and email requests to determine the status of the installation, the project was dropped from the sample. Unfortunately it was too late in the study to substitute another site, so the final sample included only two sites. A description of this site follows the table.

Table 5: RI Final Sample Selection

Stratum	Measure Type	Project ID	Evaluator	Project Description
1	Process	N571832	KEMA	Manufacturing, Efficient air-cooled process chillers
1	Compressed Air	N558912	KEMA	Manufacturing, Storage and pressure/flow controller
2	Process	N587428	KEMA	Municipal, Efficient aerator blowers at a WWTP

<u>Dropped Site 558912</u>

This measure proposed to modify and upgrade an existing compressed air system in a manufacturing plant. The system consists of two rotary screw air compressors including a 100-HP unit as the lead compressor and a 50-HP compressor, which provides trim capacity. The savings are obtained from the installation of compressed air receivers, and a pressure controller, which reduces compressor discharge pressure, and changes the sequence of operation of the existing air compressors.

A site visit was conducted to review the project and install power loggers to monitor the operation of the two compressors. The new receivers were installed and operating in-line with the compressors. The new pressure controller had also been installed. However, this new controller had been problematic and the facility was working with the manufacturer and installation contractor to resolve the operational issues. As a result, the new controller was bypassed and the system pressures could not be reduced as proposed. The original baseline operating sequence was also still in place. The existing 50-HP compressor was still providing trim operation. A significant portion of the proposed savings was derived from taking this unit offline.

The facility personnel also stated that the 50-HP unit was to be moved to another location. This unit would serve load at another part of the facility. The expansion plan called for the 50-HP unit to be dedicated to that portion of the plant. The 50-HP compressor would be isolated from the existing system but a cross connection would be provided between the two systems. This required modifications to the distribution piping that changed the baseline configuration.

All parties decided that the installing the monitoring equipment at that time would not provide usable data in light of the proposed changes and problems with the pressure controller. Facility personnel were continuing to resolve the control problem during the renovation. Evaluators were asked to reschedule the site visit for a minimum of 30-days.

The site was re-contacted 5-weeks after the first site visit. The 50-HP compressor had been moved and was operating. However, the use of the new pressure controller was still not resolved. Both the 100-HP and 50-HP compressors were operating. The new cross connection is open between the two systems creating a change in load and operation over the baseline conditions. Installing the monitoring equipment at this time was considered just as problematic since the prime driver for the measure, the pressure controller was not operating yet. Both compressors were operating together and system pressures still reflected the baseline operation and now included the distribution system changes. The facility personnel were committed to re-using the new pressure controller in the new configuration and were still working with the manufacturer and installation contractor to resolve installation issues. The changes made in the plant also suggest that the measure could be re-installed. The 50-HP unit has been relocated and placed on the opposite side of a cross connection that will isolate the two systems during normal operation. This will leave the 100-HP compressor serving the original load. Unless there are changes in production loads, this will only be possible if the new controller is fully operational.

Numerous attempts were made to visit the customer to determine the status of installation and verify that the pressure controller was being used again. Unfortunately the customer did not respond to numerous phone calls and email attempts and KEMA was not able to visit to conclude the evaluation. It was decided that since the status of the measure could not be determined, the project should be dropped from the sample. Unfortunately it was too late in the study to substitute another site so the final sample included only two sites.

3. Description of Methodology

3.1 Measurement and Evaluation Plans

Following the final sample selection of 2010 Custom Process and Compressed Air applications and prior to beginning any site visits, KEMA developed detailed measurement and evaluation plans for each of the 3 applications. The plans outlined on-site methods, strategies, monitoring equipment placement, calibration and analysis issues. National Grid provided comments and edits to clarify and improve the plans prior to them being finalized.

The site evaluation plan played an important role in establishing approved field methods and ensuring that the ultimate objectives of the study were met. Each site visit culminated in an independent engineering assessment of the actual (e.g. as observed and monitored) annual energy, on-peak energy, summer on-peak and seasonal demand, and winter on-peak and seasonal demand savings associated with each project.

3.2 Data Gathering, Analysis, and Reporting

Data collection included physical inspection and inventory, interview with facility personnel, observation of site operating conditions and equipment, and long-term metering of usage. At each site, KEMA performed a facility walk-through that focused on verifying the installed conditions of each energy conservation measure (ECM). Evaluators viewed EMS screens to verify schedules and operating parameters where applicable. Power meters and Time-Of-Use (TOU) current loggers were installed to monitor the usage of the installed equipment and associated affected spaces. EMS trends were obtained when possible for both process sites. Whole building interval load data was also obtained from National Grid for the waste water treatment facility.

Collected data was analyzed to verify implementation of each ECM, and savings analyses were performed to estimate hourly energy use and diversified coincident peak demand. Each site report details the specific analysis methods used for each project including algorithms, assumptions and calibration methods where applicable.

KEMA submitted draft site reports to National Grid upon completion of each site evaluation, which after review and comment resulted in the final reports found in Appendix A. This executive summary provides a concise overview of the evaluation methods and findings.

3.3 Analysis Procedures

In order to aggregate the individual site results from the RI Custom Process and Compressed Air samples, KEMA applied the model-assisted stratified ratio estimation methodology.[2,3] The key parameter of interest is the population realization rate, i.e., the ratio of the evaluated savings for all population projects divided by the tracking estimates of savings for all population projects. This rate is estimated for the Rhode Island populations only, as well as for National Grid's combined populations of Rhode Island and Massachusetts. Of course, the population realization rate is unknown, but it can be estimated by evaluating the savings in a sample of projects. The sample realization rate is the ratio between the weighted sum of the evaluated savings for the sample projects divided by the weighted sum of the tracking estimates of savings for the same projects. The statistical precisions and error ratios are calculated for each level of aggregation.

The results presented in the following section include realization rates (and associated precision levels) for annual kWh, % kWh on-peak and demand (kW) savings during winter and summer on-peak periods, as defined by the ISO-

[2]The California Evaluation Framework, prepared for Southern California Edison Company and the California Public Utility Commission, by the TecMarket Works Framework Team, June 2005, Chapters 12-13.

[3]Model Assisted Survey Sampling, C. E. Sarndal, B. Swensson, and J. Wretman, Springer, 1992.

NE Forward Capacity Market (FCM). All coincident summer and winter peak reductions were calculated using the following FCM definitions:

- Coincident Summer On-Peak kW Reduction is the average demand reduction that occurs over all hours between 1 PM and 5 PM on non-holiday weekdays in June, July and August.
- Coincident Winter On-Peak kW Reduction is the average demand reduction that occurs over all hours between 5 PM and 7 PM on non-holiday weekdays in December and January.

Relative precision levels and error bounds are calculated at the 80% confidence level for demand values, since that is the requirement for portfolios participating in the ISO-NE Forward Capacity Market. For all kWh realization rates, the standard 90% confidence level is used.

4. Custom Process and Compressed Air Results

Evaluated savings data for the Rhode Island sample points were analyzed to develop Rhode Island realization rates, and then combined with National Grid Massachusetts results (previously reported as discussed above) to represent overall results for use in Rhode Island.

In preparation for analyzing the evaluation results collected for the RI sample points, the original 2010 population distribution was used to calculate case weights for each observation in the Rhode Island sample. These weights reflect the number of projects that each sample point represents and allow for the aggregation of results across strata. Since one sample site was dropped from the study, the case weights are different than those in the original design. The case weights for this study are shown in the last column in Table 6.

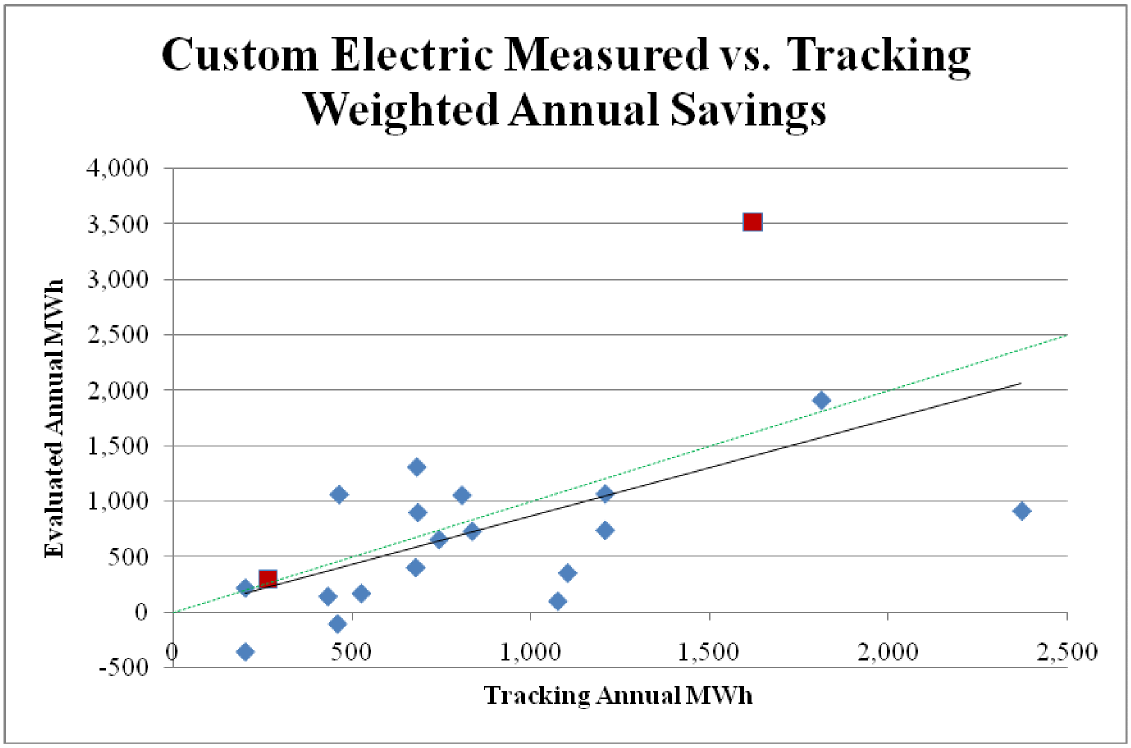
Table 6: **RI Custom Process and Compressed Air Case Weights**

State	Stratum	Maximum KWh Savings	Total Projects	Total Annual MWh	Projects in Sample	Case Weight
Rhode Island	1	269,462	8	1,100,044	1	8.00
	2	829,674	2	1,641,037	1	2.00

4.1 Major Findings and Observable Trends

Figure 1 presents a scatter plot of evaluation savings for the two Rhode Island sample points combined with the Massachusetts sample points. Each point has been weighted by the number of population projects that it represents. The dashed line represents a realization rate of one. The slope of the solid line in this graph is an indication of the realization rate, and can be seen to be less than one. However, the two Rhode Island sample points, as indicated by the two square points in the graph, were both above one.

Figure 1: Scatter Plot of RI and MA Evaluation Results for Annual KWh Savings



4.2 Presentation of Results

Table 7 presents a summary of the site level results for this impact evaluation.

Table 7: RI Custom Process and Compressed Air Detailed Site Results

		Tracking Estimated Savings				Evaluation Savings				
			On-Peak	Coincident Peak			On-Peak	Coincident Peak		
Stratum	Project ID	kWh/yr	%	Summer kW	Winter kW	kWh/yr	%	Summer kW	Winter kW	Case Weight
1	571832	33,116	48%	5.25	3.58	37,796	47%	4.50	4.00	8
2	587428	811,363	47%	106.79	72.14	1,761,204	45%	174.40	216.20	2

Table 8 summarizes the savings realization rates and primary reasons for discrepancies between the tracking and evaluation estimates of annual energy savings for the two RI sites. The site energy savings realization rates were both greater than 100%.

Table 8: RI Custom Process and Compressed Air Primary Site Discrepancies

End Use	Project ID	Realization Rates	Reasons for Discrepancies

		kWh/yr	On-Peak %	Summer KW	Winter KW	
Process	571832	114%	98%	85%	112%	Savings are greater due to increase in process tonnage and less weather sensitivity than anticipated.
Process	587428	217%	96%	163%	300%	Savings are greater due to significantly increased oxygen demand following implementation and revised oxygen transfer for the plant.

The site-level evaluation results for Rhode Island were aggregated using stratified ratio estimation. The Massachusetts results from separate Custom Process and Compressed Air samples were combined to determine a MA realization rate. Then the Rhode Island and Massachusetts realization rates were applied to their respective total tracking savings to estimate each state's total evaluated savings. The National Grid combined realization rate is the ratio of the total evaluated savings to the total tracking savings, each of which is calculated by summing across the two states. Table 9 summarizes the RI results and Table 10 shows the aggregation of the previously reported MA results to a combined Custom Process and Compressed Air category. Finally, Table 11 provides a summary of the aggregated National Grid results. Since the design criteria for the demand realization rates were different than those for the annual kWh (80% vs. 90% confidence levels), the precisions are reported only in the appropriate rows in these tables. A gray cell indicates that the confidence level shown is not applicable.

Table 9: **Summary of RI Custom Process and Compressed Air Results**

Rhode Island	Annual KWh	On-Peak KWh	% On-Peak KWh	On-Peak Summer kW	On-Peak Winter kW
Custom Process & Compressed Air					
Total Tracking Savings	2,741,081	1,314,183	47.9%	326	247
Total Measured Savings	5,553,995	2,550,836	45.9%	491	662
Realization Rate	202.6%	194.1%	95.8%	150.6%	268.6%
Relative Precision at 90% Confidence	±11.8%	±11.7%	-	na	na
Error Bound at 90% Confidence	656,646	298,312	-	na	na
Relative Precision at 80% Confidence	na	na	-	±10.6%	±14.5%
Error Bound at 80% Confidence	na	na	-	52	96
Error Ratio	0.14	0.14	-	0.17	0.23

Table 10: Summary of MA Custom Process and Compressed Air Results

Massachusetts	Annual KWh	On-Peak KWh	% On-Peak KWh	On-Peak Summer kW	On-Peak Winter kW
Custom Process					
Total Tracking Savings	11,469,099	5,239,692	45.7%	1,307	1,426
Total Measured Savings	7,767,200	3,571,996	46.0%	1,251	1,172
Realization Rate	67.7%	68.2%	100.7%	95.7%	82.2%
Relative Precision at 90% Confidence	23.9%	32.7%	-		
Error Bound at 90% Confidence	1,854,273	1,167,532	-		
Relative Precision at 80% Confidence			-	18.6%	25.5%
Error Bound at 80% Confidence			-	484	473
Error Ratio	0.84	0.82	-	1.65	1.75
Compressed Air					
Total Tracking Savings	3,936,025	1,892,576	48.1%	485	476
Total Measured Savings	3,507,180	1,575,687	44.9%	381	395
Realization Rate	89.1%	83.2%	93.4%	78.6%	83.0%
Relative Precision at 90% Confidence	34.0%	33.8%	-		
Error Bound at 90% Confidence	1,191,178	531,990	-		
Relative Precision at 80% Confidence			-	40.3%	40.5%
Error Bound at 80% Confidence			-	154	160
Error Ratio	0.57	0.51	-	0.88	0.89
Custom Process & Compressed Air					
Total Tracking Savings	15,405,124	7,132,268	46.3%	1,792	1,903
Total Measured Savings	11,274,380	5,147,683	45.7%	1,632	1,568
Realization Rate	73.2%	72.2%	98.6%	91.1%	82.4%
Relative Precision at 90% Confidence	±19.5%	±24.9%	-		
Error Bound at 90% Confidence	2,203,913	1,283,021	-		
Relative Precision at 80% Confidence			-	±31.1%	±31.9%
Error Bound at 80% Confidence			-	508	499
Error Ratio	0.75	0.85	-	1.63	1.60

Table 11: Summary of Overall MA & RI Combined National Grid Custom Process and Compressed Air Results

Rhode Island and Massachusetts	Annual KWh	On-Peak KWh	% On-Peak KWh	On-Peak Summer kW	On-Peak Winter kW
Custom Process & Compressed Air					
Total Tracking Savings	18,146,205	8,446,451	46.5%	2,118	2,149
Total Measured Savings	16,828,375	7,698,519	45.7%	2,123	2,230
Realization Rate	92.7%	91.1%	98.3%	100.2%	103.8%
Relative Precision at 90% Confidence	±13.7%	±17.1%	-		
Error Bound at 90% Confidence	2,299,656	1,317,245	-		
Relative Precision at 80% Confidence			-	±24.1%	±22.8%
Error Bound at 80% Confidence			-	511	509

From the state-level results, we can observe that the Rhode Island realization rates are significantly higher than those estimated for Massachusetts for all but the % On-peak kWh, which is slightly lower. At 13.7%, the overall precision on the Annual KWh estimate is good. All of the RI precisions are better than expected due to the fact that there were only two sites included in the final sample, and they both had positive realization rates. The demand realization rates also achieved slightly better precisions than had been anticipated.

4.3 Implications for Future Studies

From a statistical perspective, which is heavily dependent on Massachusetts results, it appears that the Custom Process results are less stable, and the variation across sample sites is greater than expected. However, the two Rhode Island Custom Process sites performed very well. Unless the underlying causes of the variability change, future designs should assume higher error ratio values to determine sample size requirements. The Compressed Air sample demonstrated somewhat less variability in Massachusetts.

4.4 Conclusions and Recommendations

Despite the positive results of the Rhode Island sites, the Custom Process and Compressed Air program appears to be producing results that are lower than expected when combined with Massachusetts. The Custom Process end-use appears to be a bit more variable than Compressed Air. Below are the DNV KEMA evaluation team findings and recommendations, which refer only to National Grid's Rhode Island sites. Additional recommendations, based on National Grid's Massachusetts sites, are available in the concurrent Massachusetts Custom Process and Compressed Air impact evaluation referenced previously.

Update energy and demand savings estimates when applying revisions from a TA Study. At the process chiller site, the TA vendor provided revised savings estimates for the measure based on new information at the site. The revised energy savings estimate was used as the updated tracking value, but the revised demand savings were not. It is recommended that if revised savings estimates are produced by the TA vendor and accepted by National Grid, both the energy and demand savings should be updated.

For large savings sites, consider alternate post-inspection options. At the WWTP site, one of the incentive requirements for the new blowers was automatic DO control via their SCADA system. Ultimately the site tried out the automatic controls, but reverted to manual control due to issues maintaining DO in each individual basin. At the time of the post-installation audit, it would have appeared as if everything was working according to plan since the DO controls were in place and operating at the time. It is recommended that for large savings sites that involve process/control changes, consider an additional follow-up phone call 6-12 months down the line to verify measure retention. Another alternative would be to allow a more time to pass before the post- installation inspection so that these site issues have had more time to stabilize.